Thermal Analysis for a Langmuir Probe to be used in a Re-entry CubeSat Mission

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Outline

• Motivation

• Literature Review

• Designs of Langmuir Probes

• Results and Discussion

• Concluding Remarks
Motivation (1/2)

• Re-entry CubeSat (3U)

• Transmit data before impact

• Langmuir probe

• OBC thermally insulated from exterior
Motivation (2/2)

- FLP located on the exterior
- Electrically conductive and thermally conductive
- Spatial considerations for heat sink
Fish, C.S., Swenson, C.M., Crowley, G. et al. 2014

• Dynamic Ionosphere CubeSat Experiment (DICE) mission

• Two identical 1.5U CubeSats with two single Langmuir probes each for in situ measurements
Literature Review (2/3)

Cacace, M., Batal, T., Corre, Y., et al. 2015

- Plasma measurements in bigger apparatus include actively cooling systems

- WEST project (W-Environment in Steady-State Tokamak)
Arrays of individually addressable probes with 600μm-diameter tips

Up to 25 probes per 1cm-square tile

Figure 4.14: Various array sizes of MEMS Langmuir probes.

Field, E.S. 2011
Design of Langmuir Probes (1/2)

• Flush mounted double probe
• Graphite head and harness
• No aerodynamic interference
• Measurement subject to CubeSat boundary
Design of Langmuir Probes (2/2)

• Needle tip triple probe

• Stainless steel, tungsten tips and harness

• Ceramic head and heat resistant adhesive filling
TPS Re-entry Temperature

*Data provided by von Karman Institute of Fluid Dynamics

**Descent ranging from 100Km-30Km
Maximum Temperatures During Re-entry

- 887 °C
- 748 °C
- 1925 °C
Results and Discussion (1/3)

- Maximum operational temperature of OBC 85°C
- Temperature at 7cm harness 87.97 °C
- Plasma contact area too big
Results and Discussion (2/3)

• Harness length of 10cm selected for testing

• At 6cm, temperature dropped from 89°C to 67°C by placing directly and behind TPS

• Minimized exposure area
Results and Discussion (3/3)
Concluding Remarks

• Needle tip triple probe selected

• Tungsten tips and harness selected

• 4mm diameter fiberglass cover for harness as heat sink

• 6cm long harness enough

• Place probe head behind Fiberfrax and SiC TPS
Thank you for your attention

Questions
Fig. 1. Leading edge of the baffle will host the Langmuir probes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Exterior reference temperature profiles

The boundary conditions for the re-entry phase are presented in the table below.

*Table 2-7: temperature boundary conditions during re-entry phase vs time and altitude, corresponding to a satellite mass of 4kg.*

<table>
<thead>
<tr>
<th>Altitude [km]</th>
<th>100</th>
<th>80</th>
<th>66</th>
<th>60</th>
<th>53</th>
<th>48</th>
<th>44</th>
<th>40</th>
<th>30</th>
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<tbody>
<tr>
<td>Time [s]</td>
<td>579.4</td>
<td>969.2</td>
<td>1059.2</td>
<td>1083.8</td>
<td>1107.0</td>
<td>1122.0</td>
<td>1133.1</td>
<td>1144.0</td>
<td>1174.0</td>
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<tr>
<td>Front Cork T [°C]</td>
<td>1099</td>
<td>1596</td>
<td>1816</td>
<td>1911</td>
<td>1925</td>
<td>1698</td>
<td>1692</td>
<td>1369</td>
<td>222</td>
</tr>
<tr>
<td>Side Cork T [°C]</td>
<td>801</td>
<td>1000</td>
<td>991</td>
<td>996</td>
<td>1002</td>
<td>1013</td>
<td>1018</td>
<td>858</td>
<td>153</td>
</tr>
<tr>
<td>TPS Sidewalls T [°C]</td>
<td>641</td>
<td>662</td>
<td>745</td>
<td>733</td>
<td>727</td>
<td>740</td>
<td>748</td>
<td>631</td>
<td>137</td>
</tr>
<tr>
<td>TPS Back T [°C]</td>
<td>138</td>
<td>194</td>
<td>144</td>
<td>267</td>
<td>283</td>
<td>274</td>
<td>273</td>
<td>216</td>
<td>117</td>
</tr>
<tr>
<td>Solar Panel Front T [°C]</td>
<td>640</td>
<td>830</td>
<td>887</td>
<td>873</td>
<td>886</td>
<td>832</td>
<td>830</td>
<td>696</td>
<td>168</td>
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<tr>
<td>Solar Panel Back T [°C]</td>
<td>445</td>
<td>537</td>
<td>525</td>
<td>482</td>
<td>462</td>
<td>455</td>
<td>463</td>
<td>412</td>
<td>141</td>
</tr>
</tbody>
</table>

This conditions are derived from CFD computations.